Scientists explain ‘kink’ in trail of the hotspot that created the Hawaiian Islands
By David F. Salisbury

Scattered around the earth are approximately 40 specific fixed areas of isolated volcanic activity known as hot spots. As the crustal plate moves over a hot spot, successive eruptions can produce a linear series of peaks or seamounts with the youngest peak above the hot spot.

—Fundamentals of Oceanography

These days, nearly every introductory textbook in geology and oceanography includes a discussion of hot spots – hot plumes of molten mantle material that sit beneath the rigid plates that form the Earth’s crust and periodically punch through them to produce outbursts of volcanic activity. Iceland, Yellowstone, the Hawaiian and Galapagos Islands were all created by hot spots.

But a deep-sea drilling expedition this summer has produced new evidence that will force the textbook authors to revise their descriptions because it indicates that one of the largest hotspots – the one that created the Hawaiian Islands – has not remained fixed through the last 80 million years, but spent the first half of its life in motion.

“This forces us to re-examine the geologic evidence we have on all the hot spots to see if any others show evidence of similar motion,” says William G. Siesser, professor of geology and a member of the international team that made the discovery.

The hot spot theory – first proposed in the 1960s – has provided one of the most dramatic proofs of plate tectonics, which holds that the Earth’s crust is broken up into a system of rigid “tectonic” plates that are in continual motion at rates of a few centimeters per year.

In the hot spot theory, a plume of hot mantle material sits just below a crustal plate and, as the plate moves past, the molten material periodically punches through the crust to create a chain of volcanic mountains. Hot spots tend to be located where the crust is thinnest, which means they are mostly found on the seafloor, where they create strings of seamounts and volcanic islands.

If you drained the Pacific Ocean, you would see a striking 5,000-mile string of seamounts and islands that runs in a straight line from the Kamchatka Peninsula in Siberia south to a point just west of Midway Island and then turns abruptly to the southeast to form the Hawaiian Island chain. This is the trail left by the hot spot that is currently under the island of Hawaii and is responsible for its volcanic activity.

While the Hawaiian Island chain provided the basic geological data that confirmed the hot spot theory, geophysicists have had trouble explaining why the hotspot’s trail should have abruptly changed direction some 43 million years ago. Scientists have tried to explain this abrupt, geologically speaking, change in direction by arguing that the Pacific plate must have changed direction at this point. Unfortunately, this doesn’t fit well with other geological evidence.

Officials of the Ocean Drilling Program – an international effort with headquarters at Texas A&M and funded by the National Science Foundation in the United States and comparable government agencies in 18 other countries – decided to schedule its specially equipped deep-sea drilling ship, Joides Resolution, to spend two months in the northern Pacific in hopes of resolving this long-standing mystery.
*Joides Resolution* is a high-tech, seagoing research center with the ability to drill and core into rock for several thousand feet below the ocean floor in areas where the ocean floor itself lies up to 27,000 feet below the surface.

“The sleeping cabins are very small, but the laboratories are quite spacious and filled with state-of-the-art equipment, as good as anything you can find on a university campus,” says Siesser, who has participated in six, two-month cruises aboard the ship.

That is appropriate because the scientists work in two 12-hour shifts. “On this cruise I was lucky, I was assigned the noon to midnight shift,” he said. That meant he would usually get up at about 11 a.m., have breakfast in the galley with a number of his comrades and then go to work.

The ship travels to carefully selected locations – in this case sites in six of the early seamounts that the Hawaii hot spot created – to drill out and extract long, cylindrical cores of rock that are brought on board. The cores contain a series of thin layers of material that were deposited on the sea floor at specific periods in the past.

The task of the scientists is to read the record of events in the history of the ocean recorded in the cores at each site. Each of the scientists on the 24-member team specializes in areas such as sedimentology, paleontology, petrology, volcanology, tectonics, geochemistry, geophysics and other areas.

Siesser’s specialty is the study of micro-organisms fossilized in the rocks. Because different species of micro-organisms lived at different periods, Siesser can date a particular layer in a core to within a million years or fewer by examining the collection of microfossils found there. His work provides the “basic calendar” that the other scientists rely upon in their analyses.

He is one of only about 10 people in the United States who studies a group of microfossils called calcareous nanoplankton that provides one of the best dating methods of the kind for the last 200 million years. These tiny marine organisms are closely related to diatoms, forams and amoebas.

When the ship reaches the spot where it is going to drill, it takes about 24 hours to lower the drill train to the seafloor. In the relatively soft material that it encounters as it begins to drill, it can produce a new nine-meter core every hour.

Each time a new core came up on his watch, Siesser took a small sample from the bottom of the core, broke it up and mixed it with a small amount of water in a test tube and spread the mixture on a microscope slide, leaving a thin residue that revealed hundreds of tiny fossils when viewed under a microscope. In this fashion, Siesser was able to identify the types of nanoplankton in the bottom layer of the core and to use the information to come up with a rough estimate of the layer’s age. He would then give that estimate to his fellow researchers before doing a more thorough analysis of the core.

The number of samples he must analyze to date the different layers in a given core depends on the length of time that it spans. The less time between the dates of the top and bottom layers, the fewer intermediate samples he must analyze. During the periods when the new cores were coming hourly, Siesser didn’t have much time to waste. But, as the drill penetrated deeper into the seafloor, the rock becomes harder and, as a result, the rate at which new cores were brought on board dropped to one every three to four hours.

“Normally, there is plenty of time to take a break, go get a cup of coffee,” he said. During the voyage, the scientists took cores from six of the seamounts in the Emperor Seamount Chain extending from Kamchatka to the Midway Island. The first of these were fairly far north so, although it was summer, the weather was cold and chilly. “There wasn’t much incentive to go for walks on deck,” Siesser says.
These cores provided the scientists with the detailed information they needed to reconstruct the hot spot's early movements. Because of the structure of Earth's magnetic field, a compass needle is horizontal at the equator, but points straight down at the North Pole. Thus, the angle of the needle is an indication of the latitude. Lava contains magnetic particles that act like compass needles and the orientation of these particles becomes fixed when the lava cools. So, by measuring the orientation of these particles in the old seamount cores, the onboard experts were able to determine the latitude at which they formed. Combining this information with Siesser's dates and relevant information about the plate's motion allowed the scientists to determine what the hot spot has been doing for the last 80 million years.

Their reconstruction indicates that, for its first 37 million years, the hot spot was moving at about the same rate as the Pacific plate, but in a different direction. The southerly direction of the Emperor Seamount Chain is the result of the sum of the motions of the hot spot and the plate. Forty-three million years ago, however, the hot spot became stationary while the plate continued to move. That is when it began producing the Hawaiian Island chain.

Last summer may be Siesser's final deep-sea drilling voyage: “After the last few trips, I've said, 'That's my last!' I've already spent an entire year at sea on these voyages. But then, a few years later when I'm asked, I've decided to go again!”

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